REPELLENCY OF FUNGICIDAL RICE SEED TREATMENTS TO RED-WINGED BLACKBIRDS

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Abstract: We evaluated the feeding responses of male red-winged blackbirds (*Agelaius phoeniceus*) to rice seed treated with fungicidal compounds in a series of 2-cup, 1-cup, and flight pen trials. Of the materials tested, Kocide® SD, a fungicide containing 30% copper hydroxide, was the most effective. Although this chemical caused mortality (due to hemolytic anemia) when applied at relatively high concentrations in the 1-cup test, birds consistently avoided it without ill effects in 2-cup and flight pen trials. Applied at the currently registered label rate, Kocide may safely and effectively repel birds feeding on newly planted rice. Currently registered fungicides and other pesticides may offer new alternatives for bird damage control.

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Bird damage to newly sown rice is a major problem to growers in southwestern Louisiana (Labisky and Brugger 1989) and east Texas where damage may exceed $4 million annually (Decker et al. 1990). In some situations, the only cost-effective solution may be to delay planting until the depredating bird population disperses (Wilson et al. 1989). Alternatively, bird repellent seed treatments have been developed and tested (e.g., Holler et al. 1982, Daneke and Decker 1988, Decker et al. 1990), but none is currently registered with the Environmental Protection Agency for use in the United States. Another approach is to identify compounds already registered for rice that are also aversive to birds. We chose to examine this possibility and focused on registered fungicides. A 1989 search of the PEST-BANK pesticide product data base (Natl. Pestic. Inf. Retrieval System, Purdue Univ.) listed 69 products as rice seed treatment fungicides. For behavioral evaluation, we selected 4 compounds on the basis of their frequency of use as rice seed treatments and/or their putative bird repellent properties.

We appreciate the cooperation of the various chemical companies in supplying samples.

(Mention of trade names does not imply endorsement by the United States Government.) J. R. Bone was particularly helpful in providing Kocide® SD material. L. R. Haefele kindly provided unpublished reports on Panoctine feeding trials. Thanks go to M. O. Way for supplying the rice used in our study. We are grateful to C. O. Nelms for capturing the redwings and to L. A. Whitehead for preparing the manuscript. G. Lee assisted with necropsies of test birds and provided insight into the causes of death. C. E. Knittle, J. R. Mason, and S. B. White provided constructive comments on earlier drafts.

METHODS

Test Materials

Dithane® M-45 (Rohm and Haas Co., Philadelphia, Pa.) contains 80% (g/g) mancozeb as the active ingredient. Mancozeb, which is a mixture of manganese and zinc ethylene bisdithiocarbamate, has very low acute oral toxicity to rats (Smith 1987), and the dietary toxicity of a closely related compound, maneb, to *Coturnix* quail exceeds 5,000 ppm (Hill and Camardese 1986). Smith (1987) estimated that mancozeb is used on 400,000–2 million hectares of crops annually. To our knowledge, the bird repellent properties of mancozeb have not been previously examined.

Gustafson 42-S® (Gustafson, Inc., Dallas, Tex.) contains 42% (g/g) thiram, tetramethylthiuram disulfide, as the active ingredient. Thiram has low acute oral and dietary toxicity (Smith 1987), and several studies document its bird repellent properties (e.g., Young and Zevallos 1960, Schafer et al. 1977, Sandhu et al. 1987). Thiram is not a widely used agricultural chemical (<40,000 ha annually [Smith 1987]).

Kocide SD (Griffin Corp., Valdosta, Ga.) contains 30% (g/g) copper hydroxide, one of several copper-based compounds that are exempt from residue tolerances (Farm Chem. Handb. 1987). Copper-based compounds have been used widely for controlling fungus and algae with little apparent adverse environmental consequence (Owen 1981). Babu (1988) found copper oxychloride, a fungicide similar to copper hydroxide, to be repellent to house sparrows (*Passer domesticus*).

Panoctine® (KenoGard VT, Stockholm, Sweden) is a fungicidal treatment used widely throughout the world on small grain, but it is not registered for use in the United States. The active ingredient is guazitine triacetate. Unpublished reports provided by the manufacturer show that Panoctine is repellent to "pheasants, crows, and pigeons," and the product label states that it "acts as a repellent to certain important bird species."

We prepared treated seeds in 1-kg batches by adding the appropriate amount of fungicide to 45 mL of water and slowly mixing this with the seeds for 10 minutes in a rotating tumbler. Seeds were air-dried and stored in polypropylene bottles in an air-conditioned laboratory.

General Procedures

Initially, we performed feeding trials in which 2 cups of food were presented simultaneously (2-cup test). These results served to rank the effectiveness of the 4 candidate fungicides. Next, the 2 most effective materials were evaluated in a trial in which only 1 cup of food was presented (1-cup test). Finally, we conducted a flight pen test of the most promising compound.

The study took place at the Denver Wildlife Research Center's Florida Field Station in Gainesville. Male red-winged blackbirds were trapped locally and held in captivity 1–3 months prior to testing. We conducted 1- and 2-cup feeding trials in a roofed outdoor aviary. Individual test cages (45 × 45 × 90 cm) were visually isolated and equipped with automatic waterers. Test food (rough rice) and maintenance diet (F-R-M® game bird conditioner, Flint River Mills, Inc., Bainbridge, Ga.) were presented in clear plastic feed cups (8.2-cm diam, 3.8-cm high) with a circular opening (3.1-cm diam) in the top.

Two-Cup Test

Four days before the start of the test, redwings were taken from their holding cages, weighed, and randomly assigned to test cages. We formed treatment groups of 5 birds each by assigning the heaviest bird to the first group, the next heaviest to the second group, and so on. After 1 bird was assigned to each treatment group, the order of assignment was reversed. This procedure was designed to equalize consumption among groups. During the 4 days following group assignment, birds were adapted to the study regimen, which remained in effect thereafter. At 0700 hours, we removed maintenance food from each cage, and at 0900 hours we put test food (30 g of rough rice) into the cage. Test food was removed at 1500 hours and replaced with maintenance food. For each of 3 days during the acclimation period, spillage measured for 10 birds was directly proportional to consumption. Thus, spillage was not measured during the pretreatment and treatment periods.

A 5-day pretreatment period followed adaptation. During this period, each bird was presented with untreated rough rice in each of 2 cups whose positions were alternated daily. For purposes of analysis, one of these cups was randomly designated Cup A and the other Cup B. Cup A contained the treated rice during the treatment period. After a 2-day break, during which the birds had continuous access to their maintenance diet, each of the 14 groups received a different treatment. Twelve groups received fungicide-treated rice in Cup A and plain rice in Cup B. We tested each of the 4 fungicides at 3 levels: 0.01, 0.1, and 1.0% (g/g). An additional group received 0.1% (g/g) methiocarb (Mesurol® 75% wettable powder, Mobay Chemical Corp.) and served as a repellent standard for the other treatments. Finally, a control group received untreated rice during both the pretreatment and treatment periods.

A 3-way repeated measures ANOVA was conducted on the rice consumption data. Main effects were treatment, period (pretreatment or treatment phase), and food cup (Cup A, which contained the treated rice during the treatment period, or Cup B). We used Tukey's HSD test (Steel and Torrie 1980) to isolate significant ($P < 0.05$) differences among means post hoc.

At the end of the 5-day treatment period, test birds were reweighed and released. Changes in body mass among the treatment groups over the course of the trial were examined in a 1-way ANOVA.

Kocide SD contains a reddish dye, and birds may discriminate against treated seed on the basis of color. Therefore, we conducted an additional trial and exposed 5 birds to 1% Kocide SD-treated rice with similarly-dyed untreated rice as the control.

One-Cup Test

We selected Panoctine and Kocide SD for further evaluation because of their superior repellency in the 2-cup test. During treatment, different groups of birds were presented with each of these compounds at 4 levels: 0.1, 0.22, 0.5, and 1.12% (g/g). There was also a 0.1% methiocarb group and a control group. Test procedures were the same as those in the 2-cup test except that each cage contained just 1 food cup. We used a 2-way repeated measures ANOVA to evaluate the effectiveness of each treatment in reducing rice consumption in the absence of an untreated alternative food. Treatment and test period were the main effects.

Flight Pen Trial

We selected Kocide SD for flight pen evaluation based on the feeding suppression it produced in the 1-cup test. Kocide is currently registered for rice seed treatment, and we chose to apply it at a rate equal to the midpoint of the range specified on the product label, i.e., 6 fluid oz Kocide SD per 100 lb rice, or about 0.1% (g/g). One kg of treated rice was evenly distributed over a 9- × 12-m plot within the 0.2-ha flight pen at the Florida Field Station (Daneke and Avery 1989). A second 9- × 12-m plot was similarly sown with untreated rice. The remainder of the flight pen was plowed ground or grass.

In each 9- × 12-m plot, we randomly placed 10 sampling quadrats (0.19 m^2). The initial seed count on each quadrat was set at 50, and the numbers of seeds removed by the birds from these quadrats formed the basis for evaluating the birds' response to the Kocide SD treatment.

We tested 4 groups of 12 male redwings. The birds were removed from their holding cages, banded, weighed, and placed in a 3.1- × 9.3- × 1.9-m enclosure within the flight pen with free access to water, game bird conditioner, and rough rice. Following 2 days of acclimation, we released each group of birds into the flight pen and allowed them to forage undisturbed. After 3 days, the seeds on the sampling quadrats were counted, and the test birds were recaptured, weighed, and released. Final seed counts were compared among replicates with a paired t-test.

We observed the birds each morning from a blind at the north end of the flight pen. The locations of birds were recorded at 1-minute intervals for 60 minutes. The daily total number of bird observations on the treated and untreated plots was compared across days in a 2-way repeated measures ANOVA.

RESULTS

Two-Cup Test

Bird masses remained constant ($F = 0.27$; 13,52 df; $P = 0.984$) across groups throughout the test. All birds survived the test.

Total rice consumption did not differ among

Table 1. Analysis of variance on daily rice consumption by red-winged blackbirds during 2-cup repellency trials, Gainesville, Florida, 1989. Treatments were 4 fungicides (Kocide SD, Panoctine, thiram, and Dithane) at 3 levels each (0.01, 0.1, 1.0%), plus methiocarb (0.1%) and a control group. Periods were pretreatment and treatment. Cup A contained treated rice in the treatment period, and Cup B always held untreated rice.

Source	df	SS	MS	F	P
Treatment	13	140.25	10.79	0.53	0.894
Error	56	1,134.14	20.25		
Period	1	32.25	32.25	9.90	0.003
Period × treatment	13	27.74	2.13	0.65	0.797
Error	56	182.44	3.26		
Cup	1	1,552.84	1,552.83	133.85	<0.001
Cup × treatment	13	1,398.26	107.56	9.27	<0.001
Error	56	649.67	11.60		
Treatment × period × cup	13	1,469.02	113.00	29.04	<0.001
Error	1,176	4,576.53	3.89		
Total	1,399	12,519.55			

treatment groups (Table 1), but consumption was higher during pretreatment (Tables 1 and 2). There was no interaction between period and treatment, indicating that the lower rice consumption in the treatment period was independent of treatment (Table 3).

Less rice was eaten from Cup A than from Cup B (Tables 1 and 2). The cup × period interaction was significant; during pretreatment, rice consumption was equal between cups, whereas during the treatment period, consumption shifted to the untreated rice in Cup B (Table 2). The significant cup × treatment interaction reflected the fact that the extent of feeding from Cup A (treated rice) was determined by the level of treatment; higher treatment rates caused more feeding from Cup B. The significant 3-way interaction showed that the differential use of the food cups by some treatment groups occurred in the treatment period only.

Post hoc pairwise analysis revealed that several groups, i.e., Panoctine 0.1 and 1.0%, Kocide SD 0.1 and 1.0%, thiram 1.0%, Dithane 1.0%, and methiocarb 0.1% differed significantly ($P < 0.05$) from the control group in consumption of treated rice (Fig. 1).

Table 2. Overall food consumption by 140 red-winged blackbirds in 2-cup repellency trials during the pretreatment and treatment periods, Gainesville, Florida, 1989.

	Daily consumption (g/bird)					
	Cup A[a]		Cup B		Total	
Period	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Pretreatment	5.2	0.2	5.4	0.2	10.6	0.2
Treatment	2.9	0.2	7.0	0.3	9.9	0.2

[a] Cup A held treated rice during the treatment period, Cup B always held untreated rice.

The color of the untreated control rice did not appear to affect the birds' consumption of Kocide SD-treated rice. Pretreatment rice consumption was similar between groups (Table 4), and each group displayed a marked reduction in consumption of Kocide SD-treated seed during the treatment phase. However, total rice consumption with dyed control seed was somewhat reduced relative to groups given undyed control seed.

One-Cup Test

Because several birds died on Day 5 of this trial, only data from the first 4 pretreatment and treatment days were included in the analysis (Table 5). Overall, differences among treatments, between periods, and a treatment × pe-

Table 3. Food consumption by test groups of red-winged blackbirds during the pretreatment and treatment phases of 2-cup repellency trials, Gainesville, Florida, 1989.

		Daily consumption (g/bird/cup)			
	Concentration	Pretreatment		Treatment	
Chemical	(%, g/g)	$\bar{x}$	SE	$\bar{x}$	SE
Thiram	0.01	5.3	0.2	5.2	0.4
	0.1	5.1	0.4	4.7	0.3
	1.0	5.3	0.2	5.0	0.6
Dithane	0.01	5.3	0.4	4.4	0.3
	0.1	4.9	0.3	4.8	0.4
	1.0	5.2	0.3	5.0	0.6
Kocide SD	0.01	6.3	0.4	5.7	0.3
	0.1	5.6	0.4	5.2	0.5
	1.0	5.0	0.2	5.1	0.6
Panoctine	0.01	4.9	0.3	4.8	0.7
	0.1	5.8	0.5	5.1	0.7
	1.0	5.3	0.4	5.0	0.8
Methiocarb	0.1	4.8	0.4	4.6	0.6
Control		5.2	0.3	5.1	0.2

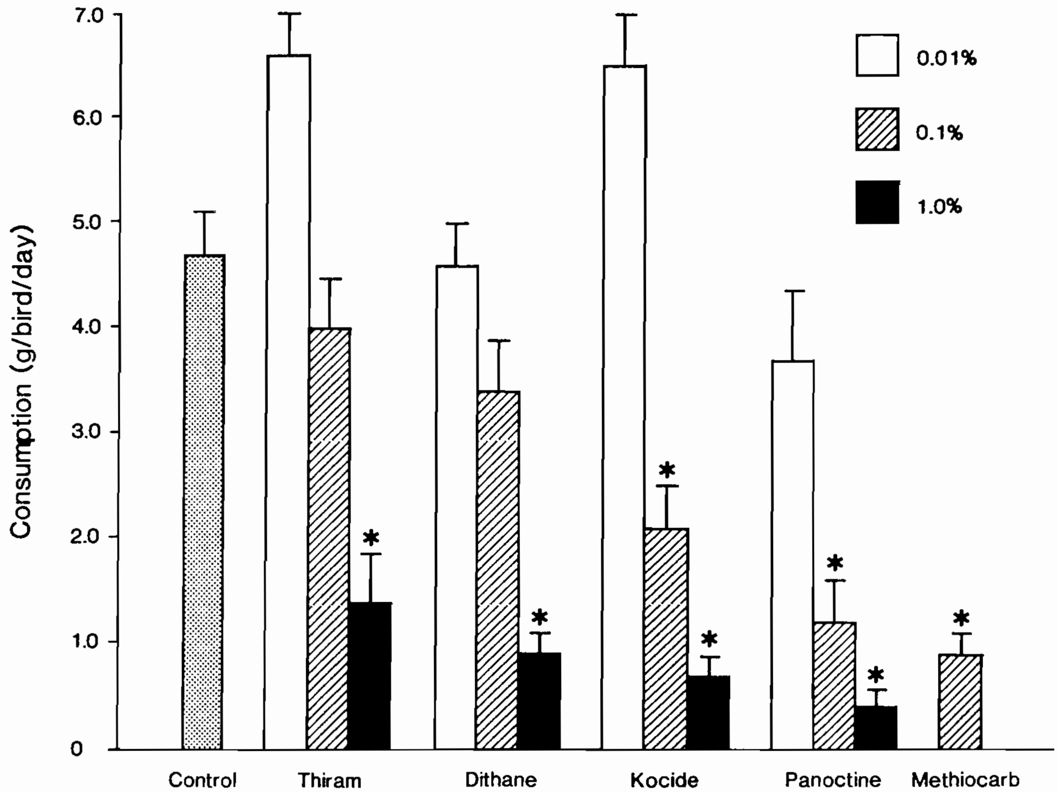

Fig. 1. Mean daily consumption by red-winged blackbirds of rice treated with fungicides at various rates during the treatment phase of 2-cup feeding trials. Capped bars indicate 1 standard error, and asterisks denote a significant ($P < 0.05$) difference from the control group.

riod interaction were significant. There were no differences ($P > 0.05$) among groups in consumption during pretreatment, and the Kocide SD 0.1%, Panoctine 0.1%, and control groups maintained their consumption levels in the treatment period. However, all other groups showed significant ($P < 0.05$) reductions in consumption during the treatment period. Greatest suppression of consumption was exhibited by the Kocide SD 1.12%, methiocarb 0.1%, and Kocide SD 0.5% groups (Table 6).

There were significant differences ($F = 18.32$; 9,40 df; $P < 0.001$) among groups in mass loss during the 1-cup test. The most pronounced loss of mass and mortality occurred in the Panoctine 1.12%, Kocide SD 1.12%, and Kocide SD 0.5% treatment groups (Table 6). These groups plus the methiocarb group did not differ among themselves ($P > 0.05$) in mean mass loss and together included 14 of the 15 fatalities. Only the lowest level Kocide SD treatment and the 2 lowest Panoctine treatments exhibited mass changes not different ($P > 0.05$) from the controls.

Gross necropsies revealed large amounts of blood throughout the digestive tracts of the birds that died in the Kocide SD and Panoctine groups. The kidneys, livers, and lungs of these birds were much paler than normal, and the body cavities of some of the birds appeared jaundiced.

Flight Pen Test

The total number of seeds taken from sampling quadrats in the treated plots ranged from 1 to 20, compared to a range of 74–240 seeds removed from quadrats in untreated plots (Ta-

Table 4. Mean daily rice consumption by red-winged blackbirds exposed to 1% Kocide SD-treated rice and control rice that was either undyed or dyed to resemble the Kocide rice, Gainesville, Florida, 1989.

	Total consumption (g)		Consumption from Cup A[a] (g)	
Test period	Undyed	Dyed	Undyed	Dyed
Pretreatment	10.1	10.7	5.1	5.1
Treatment	10.2	6.8	0.7	0.3

[a] Cup A held treated rice during the treatment period

Table 5. Analysis of variance on daily rice consumption during 1-cup trials by male red-winged blackbirds, Gainesville, Florida, 1989. Treatments were Kocide SD (0.1, 0.22, 0.5, and 1.12%), Panoctine (0.1, 0.22, 0.5, and 1.12%), methiocarb (0.1%), and a control group. Periods were pretreatment and treatment.

Source	df	SS	MS	F	P
Treatment	9	1,119.15	124.35	3.61	0.002
Error	40	1,375.97	34.40		
Period	1	2,635.80	2,635.80	381.42	<0.001
Treatment × period	9	1,073.38	119.26	17.26	<0.001
Error	340	2,349.58	6.91		
Total	399	8,553.88			

ble 7). Overall, seed loss was significantly (t = 3.59, P = 0.032) less in treated plots (2.2%) than untreated plots (31.9%). Bird observations supported these results; there was significantly (F = 43.21; 1,6 df; P < 0.001) less use of the treated plots than of the untreated plots. Differences in total plot use across days (F = 0.61; 2,12 df; P = 0.56) and the treatment × day interaction (F = 2.34; 2,12 df; P = 0.098) were not significant even though the use of treated plots steadily declined over the 3-day trial. Changes in the masses of test birds were negligible, ranging among groups from an average loss of 4.1 g to an average gain of 1.0 g. All birds survived the test.

DISCUSSION

Copper toxicity in birds, characterized by a rapid breakdown of red blood cells resulting in anemia and jaundice, is not well studied (Owen 1981). Our observations suggest that red-winged blackbirds are sensitive to the hemolytic action of copper, and the necropsy results indicate that this was directly responsible for the mortality. Hemolytic anemia caused by copper toxicity has been reported in chickens (Goldberg et al. 1956) but to our knowledge in no other avian species.

Unlike redwings in the 1-cup test, birds in the 2-cup and flight pen tests avoided eating lethal amounts of copper hydroxide. Avoidance was probably not through visual cues, because even when the treated and untreated rice looked alike (to us at least), the birds still avoided the Kocide SD-treated rice (Table 4). Avoidance may have been through rapid feedback following the onset of postingestional physiological effects caused by the copper. Alternatively, the birds may have detected subtle taste or texture differences between the treated and untreated rice. This latter possibility seems relatively unlikely because the neutral pH of avian saliva (6.75–6.88 [Leasure and Link 1940]) does not favor the release of copper ions.

MANAGEMENT IMPLICATIONS

The results of our flight pen test suggest that in a free-flying situation, with numerous foraging options available, red-winged blackbirds

Table 6. Daily rice consumption, mass loss, and mortality among red-winged blackbirds (n = 5 birds/group) during pretreatment and treatment periods of 1-cup feeding trials, Gainesville, Florida, 1989.

		Rice consumption (g/bird)					
		Pretreatment		Treatment			
Chemical	Concentration (%, g/g)	$\bar{x}$	SE	$\bar{x}$	SE	Mass loss (%)	Deaths
Kocide	0.1	12.4	1.0	10.2	0.7	−5.4	0
	0.22	11.1	0.9	6.3	0.6	11.3	1
	0.5	12.4	0.9	3.9	0.6	23.3	4
	1.12	11.7	0.5	1.3	0.3	29.3	4
Panoctine	0.1	12.2	1.1	10.0	0.7	0.7	0
	0.22	9.9	0.4	7.2	0.9	10.1	0
	0.5	11.0	0.5	5.6	0.5	12.3	0
	1.12	11.7	1.0	4.5	0.7	30.1	5
Methiocarb	0.1	11.1	0.8	2.7	0.2	16.6	1
Control		11.1	0.5	11.5	0.5	−3.3	0

Table 7. Seed removal and bird use of experimental plots sown with Kocide-treated rice seed and untreated rice seed, Gainesville, Florida, 1990.

	No. seeds removed		Plot use (bird-min)	
Group	Treated	Untreated	Treated	Untreated
1	13	74	93	259
2	10	240	86	301
3	1	208	9	405
4	20	116	110	353
$\bar{x}$	11.0	159.5	74.5	329.5
SE	3.9	38.8	22.4	31.7

will choose not to feed on rice seed treated with Kocide SD at an allowable registered rate of 6 fluid oz per 100 lb rice, or 0.1% (g/g). Furthermore, under these conditions, there was no adverse effect to the birds. In the field, birds will have even more foraging options than in the flight pen, which will probably facilitate the repellent effect of a Kocide SD treatment. We do not expect this or any other repellent treatment to eliminate all bird damage to rice. But, as the majority of the birds in an area learn to avoid treated seed, damage should decline.

Kocide SD is relatively inexpensive (approx $3/ha to treat rice), and it might also be useful as a bird deterrent seed treatment on other crops (e.g., corn, lettuce, sugar beets). Such uses might have particular relevance abroad where safe, low-cost crop protection strategies are frequently sought (e.g., Babu 1988).

In general, the evaluation of the bird repellent properties of registered agricultural chemicals has broad utility in the development of integrated agricultural pest management schemes. For example, thiram, which is registered as a fungicide for use on turf and lawns, may also deter grazing by geese (R. Dolbeer, Denver Wildl. Res. Cent., unpubl. data; J. Cummings, Denver Wildl. Res. Cent., unpubl. data), a major management problem in many areas (Conover and Chasko 1988). Sevin XLR Plus®, an insecticide registered for use on ripening rice, may also discourage rice field use by depredating blackbirds for at least 3 days (M. O. Way, Tex. A&M Univ. Agric. Res. Ext. Cent., Beaumont, unpubl. data). Registration costs for new management materials are becoming prohibitive, especially for such low-volume uses as the control of regional and seasonal avian crop depredations (e.g., Tobin and Dolbeer 1987). Thus, the most viable means for developing new bird control tools in the near future may be to expand the use of already registered materials.

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